

Chemistry 121
The University of British Columbia
Midterm Examination II
November 16, 2010

Put the first letter
of your family/last
name in this box.

Time: 60 minutes

Family/Last Name (printed): _____

First Name: _____

Signature: _____

Student Number: _____

Please check \checkmark your lecture section:

- 101 (MWF 1:00) Wolf
 102 (MWF 2:00) Chou
 103 (MWF 3:00) MacLachlan
 110 (MWF 10:00) Gates
 111 (MWF 11:00) Krems
 122 (T,Th 2:00) Lekhi
 133 (T,Th 3:30) Kunz
 188 (T,Th 8:00) Kunz
 199 (T,Th 9:30) McIntosh

INSTRUCTIONS

1. Write all answers on this examination paper, and show full details of your solutions for Part 2.
2. Read each question carefully.
3. Check that this examination consists of **12 PAGES PRINTED ON BOTH SIDES**. The last sheet (pages 11 and 12), containing "Potentially Useful Information" and the Periodic Table, may be detached for ease of use.
4. The only calculator allowed is the Sharp EL-510R. All other calculators will be confiscated. Cell phones or other electronic communication devices are not permitted.
5. Unassembled molecular model kits may be used.

RULES GOVERNING FORMAL EXAMINATIONS

1. Each candidate must be prepared to produce, upon request, a UBCcard for identification.
2. Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions.
3. No candidate shall be permitted to enter the examination room after the expiration of 15 minutes from the scheduled starting time, or to leave during the first 15 minutes of the examination.
4. Candidates suspected of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action:
 - having at the place of writing any books, papers or memoranda, calculators, computers, sound or image players/recorders/transmitters (including telephones), or other memory aid devices, other than those authorized by the examiners;
 - speaking or communicating with other candidates; and
 - purposely exposing written papers to the view of other candidates or imaging devices.
 The plea of accident or forgetfulness shall not be received.
5. Candidates must not destroy or mutilate any examination material; must hand in all examination papers; and must not take any examination material from the examination room without permission of the invigilator.
6. Candidates must follow any additional examination rules or directions communicated by the instructor or invigilator.

Marks

Part	Question	Possible Marks	Marks
1		14	
2	1	6	
	2	3	
	3	7	
	4	8	
	5	8	
	6	7	
	7	7	
Total		60	

Part 1. Multiple Choice (14 marks total)

For each numbered statement below, circle the letter that corresponds to the best answer. There is only one correct answer per question. Each question answered correctly is worth 2 marks.

1. Which of the following atomic orbitals does not exist?

- (a) $4s$
- (b) $2p_z$
- (c) $4p_x$
- (d) $2d_{xy}$
- (e) $43d_{x^2-y^2}$

2. Which of the following statements is true?

- (a) Ice has a lower density than liquid water due to hydrogen bonding.
- (b) Water molecules are non-polar.
- (c) Upon freezing, water forms a network covalent solid.
- (d) Water has a higher boiling point than hydrogen sulfide because the London forces between water molecules are stronger.
- (e) Water vapor contains H_2 and O_2 .

3. Arrange the following species in order of increasing melting point.



- (a) $Ar < CH_3OH < H_2O < I_2 < Al_2O_3$
- (b) $CH_3OH < H_2O < I_2 < Al_2O_3 < Ar$
- (c) $Ar < CH_3OH < H_2O < Al_2O_3 < I_2$
- (d) $Ar < H_2O < CH_3OH < I_2 < Al_2O_3$
- (e) $H_2O < I_2 < Al_2O_3 < CH_3OH < Ar$

4. A quantum particle (e.g. electron) can never be at rest. Why?

- (a) As a result of Planck's equation.
- (b) As a result of the Heisenberg Uncertainty Principle.
- (c) As a result of the Photoelectric Effect.
- (d) Because the speed of light is a constant.
- (e) As a result of wave interference.

5. Blue laser pointers emit light at 473 nm. What is the energy of blue laser pointer photons in J?
- (a) 4.20×10^{-28} J
 - (b) 4.20×10^{-19} J
 - (c) 1.04×10^{-39} J
 - (d) 1.04×10^{-48} J
 - (e) 4.20×10^{-37} J
6. Which of the following is an allowed transition for a one-electron atom?
- (a) $4p \rightarrow 4s$
 - (b) $2p \rightarrow 4f$
 - (c) $3d \rightarrow 1s$
 - (d) $4d \rightarrow 3f$
 - (e) $5s \rightarrow 2p$
7. Which of the following substances reacts immediately upon exposure to oxygen at room temperature?
- (a) ammonia
 - (b) sulfur
 - (c) cesium
 - (d) xenon
 - (e) silica

Part 2. Short Answer Questions

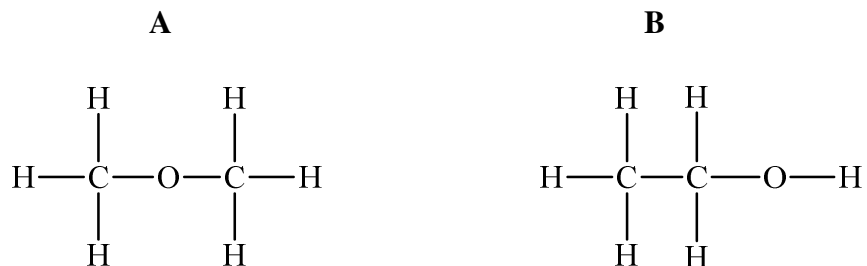
6 marks 1. For this question, consider only the following elements as possible answers:

Al, Si, P, S, Cl, Ar

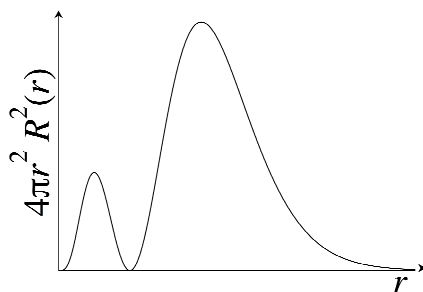
For each part, give the symbol from the above list that makes the statement correct.

- (a) _____ often forms a 2- anion in its compounds.
- (b) _____ does not form an isolable compound with fluorine.
- (c) _____ is a reactive metal.
- (d) _____ has the highest natural abundance of the elements on the list.
- (e) _____ in its elemental form is a reactive gas.
- (f) _____ is a constituent element of DNA.

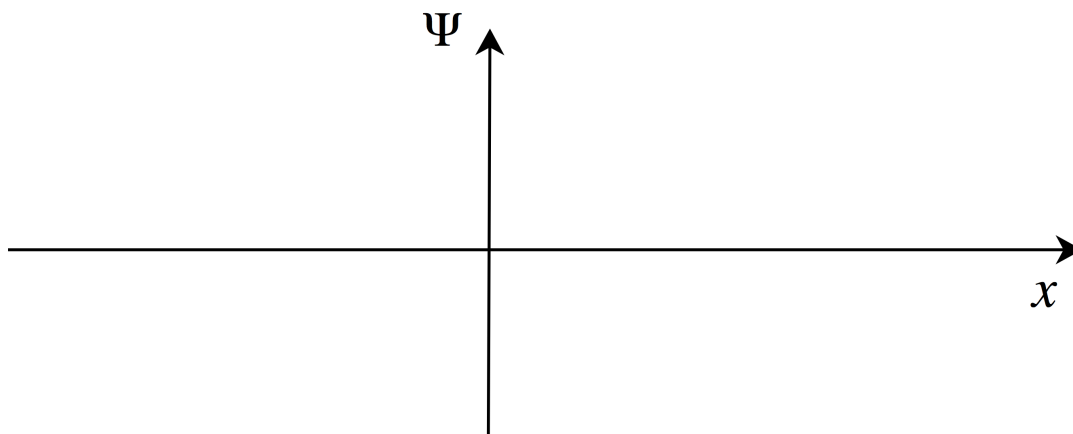
3 marks 2. The skeletal structures of two compounds with the same chemical formula C_2H_6O are shown below. Which compound (**A** or **B**) has the higher boiling point? Provide a rationale for your answer.



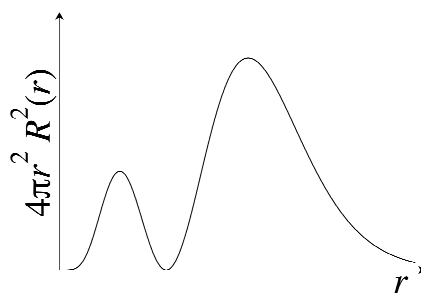
8 marks 5. The sketch below shows the radial probability distribution for the $3p_x$ orbital.



- (a) The number of radial nodes in this orbital is _____ .
- (b) The number of angular nodes in this orbital is _____ .
- (c) Sketch Ψ vs x for this orbital on the axes below.



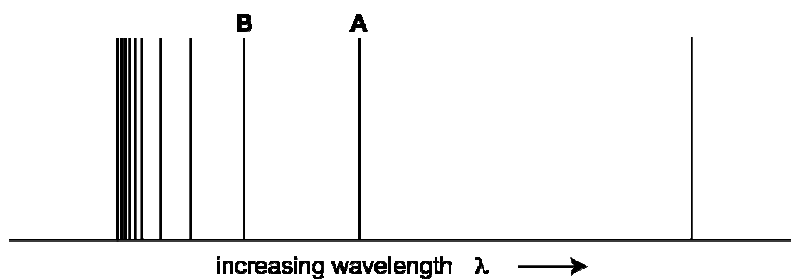
- (d) The sketch below shows the radial probability distribution for an orbital with $n = 4$. For this orbital, the wavefunction is zero when the spherical polar angle $\phi = 45^\circ$ or 135° .



Identify the orbital: _____

7 marks

6. The emission spectrum below for a one-electron species in the gas phase shows all of the lines resulting from transitions to the ground state from higher energy states. Line **A** has a wavelength of 25.65 nm.



- (a) Complete the following table to show the initial and final principal quantum numbers corresponding to lines A and B:

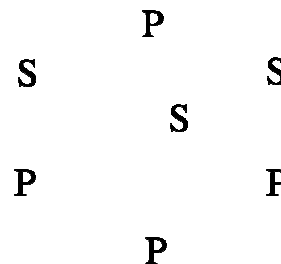
	initial principal quantum number	final principal quantum number
line A		
line B		

- (b) What is the frequency (in Hz) of light for the transition corresponding to line **A**?

- (c) Using a sample of the above one-electron species in a sealed glass tube as a light source, a chemist shines the light corresponding to only line **B** on a metal plate of gold. Given that the binding energy of gold is 8.7×10^{-19} J, calculate the kinetic energy (in J) of the ejected electrons.

- 7 marks** 7. P_4S_3 is used in the tips of “strike anywhere” matches. Burning P_4S_3 in air gives two products **X** and **Y**. Compound **X** has a molecular weight of 283.9 g/mol. Compound **Y** is 50 % oxygen by weight and is a common source of acid rain in the atmosphere. Compound **X** (0.1 mol) reacts with water (0.6 mol) to form compound **Z** (0.4 mol).

(a) Complete the Lewis structure of P_4S_3 by adding lines and dots to the following template. Show all lone pairs of electrons as pairs of dots and all bond pairs as lines.



(b) Identify compounds **X**, **Y**, and **Z**.

X:

Y:

Z:

(c) Draw the best Lewis structure for compounds **Y** and **Z**. Draw only one resonance structure if resonance is possible. Show all lone pairs of electrons as pairs of dots and all bond pairs as lines.

Y:

Z:

End of Examination

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Supplementary Sheet

Potentially Useful Information:

$$1 \text{ Hertz} = 1 \text{ Hz} = 1 \text{ s}^{-1} = 10^{-6} \text{ MHz}$$

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$1 \text{ m} = 10^6 \mu\text{m} = 10^9 \text{ nm} = 10^{12} \text{ pm} = 10^{10} \text{ \AA}$$

$$h = \text{Planck's constant} = 6.626 \times 10^{-34} \text{ J s}$$

$$N_A = \text{Avogadro's number} = 6.022 \times 10^{23} \text{ mol}^{-1}$$

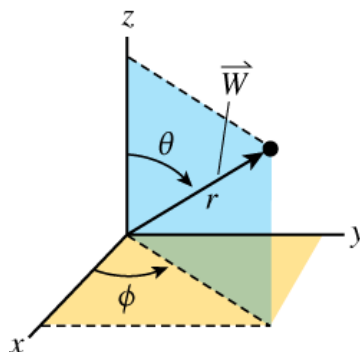
$$c = \text{speed of light} = 3.00 \times 10^8 \text{ m s}^{-1}$$

$$1 \text{ amu} = 1 \text{ u} = \text{atomic mass unit} = 1.66 \times 10^{-27} \text{ kg}$$

$$\text{electron mass} = 9.11 \times 10^{-31} \text{ kg}$$

$$\text{proton mass} = 1.67 \times 10^{-27} \text{ kg}$$

$$a_o = \text{Bohr radius} = 0.53 \text{ \AA}$$



Spherical polar coordinates

$$x^2 + y^2 + z^2 = r^2$$

$$x = r \sin \theta \cos \phi$$

$$y = r \sin \theta \sin \phi$$

$$z = r \cos \theta$$

Particle in a one-dimensional box:
$$E_n = \frac{h^2 n^2}{8mL^2}$$

For one-electron species:

$$E_n = -2.18 \times 10^{-18} \frac{Z^2}{n^2}$$

PERIODIC TABLE OF THE ELEMENTS

Group														17	18		
1	2											13	14	15	16	1	2
1.008 H												1.008 H	4.003 He				
3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.99	12 Mg 24.305	3	4	5	6	7	8	9	10	11	12	26.982 Al	28.085 Si	30.974 P	32.064 S	35.453 Cl	39.948 Ar
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.9	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.7	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc "(98)"	44 Ru 101.07	45 Rh 102.9	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.33	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.98	84 Po "(209)"	85 At "(210)"	86 Rn "(222)"
87 Fr 223	88 Ra 226.03	89 Ac# 227.03	104 Rf	105 Db [261]	106 Sg	107 Bh	108 Hs	109 Mt									

* 58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 145	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
# 90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 260